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DATA DESCRIPTOR

A new geodatabase of fuel treatments across federal lands in the USA

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Catastrophic wildfires threaten landscapes across the United States, and fuel treatments are key to mitigating this risk. Yet, information regarding when, where, and what types of treatments have occurred is scattered across multiple systems of record. Limited accessibility and utility of these data have impeded the coordinated tracking of treatment implementation and assessment of treatment effectiveness. Here, we present the Treatment and Wildfire Interagency Geodatabase (TWIG): a database that combines fuel treatment data from the U.S. Forest Service and U.S. Department of the Interior systems of record, making them easily accessible and interpretable. TWIG aims to provide the most complete nationwide database of fuel treatments, offering a wide range of land management, policymaking, and research applications.

Background & Summary

Catastrophic wildfires increasingly threaten landscapes across the United States. Historic fire suppression and climate change have created higher fuel loads and longer, more severe fire seasons[1], which have increased the total area burned and the area burned at high severity over the past two decades[2]. Fuel treatments—management actions intended to modify fire behavior by reducing or rearranging woody fuel—have been identified as the most effective way to mitigate the risk of catastrophic wildfire[3,4]. Though actual expenditures are difficult to track, the United States Department of Agriculture (USDA) Forest Service alone likely spent over $3B on fuel treatments in the last decade (data from: https://apps.fs.usda.gov/arcx/rest/services/EDW/EDW_HazardousFuelsTreatments_01/MapServer). Yet, wildfires continue to grow larger and more extreme[5]. To manage this risk, we must understand where, when, and how fuel treatments have interacted with wildfires[6]. Data regarding these interactions are vital for managers to decide where to locate future treatments and for researchers to understand when, why, and under what conditions treatments can change wildfire outcomes.

Despite major investments in fuel treatments, tracking and reporting of treatments have proven difficult. Treatments are implemented with diverse funding sources and by multiple agencies and non-governmental organizations (NGOs), and they often cross jurisdictional boundaries. As a result, there are multiple systems of record and a variety of ways to access data, including a range of tools and applications for decision support, fire modeling, and operational planning. However, many of these tools are only accessible to federal employees (e.g. the Fuel Treatment Effectiveness Monitoring or FTEM application, https://iftdss.firenet.gov/firenetHelp/help/pageHelp/content/10-ftem/ftemabout.htm) or include only a portion of the existing fuel treatment data. Limited accessibility and the difficulty of collating and comparing data from multiple sources have impeded the tracking of treatment implementation and assessments of treatment effectiveness, especially for researchers who are not already familiar with the current systems of record. For example, researchers are often required to collate fuel treatment data from multiple sources[7], inspect aerial imagery to check for missing data[8], or restrict sampling locations to jurisdictions where data is available[9]. This problem was recognized in the 2021 Infrastructure

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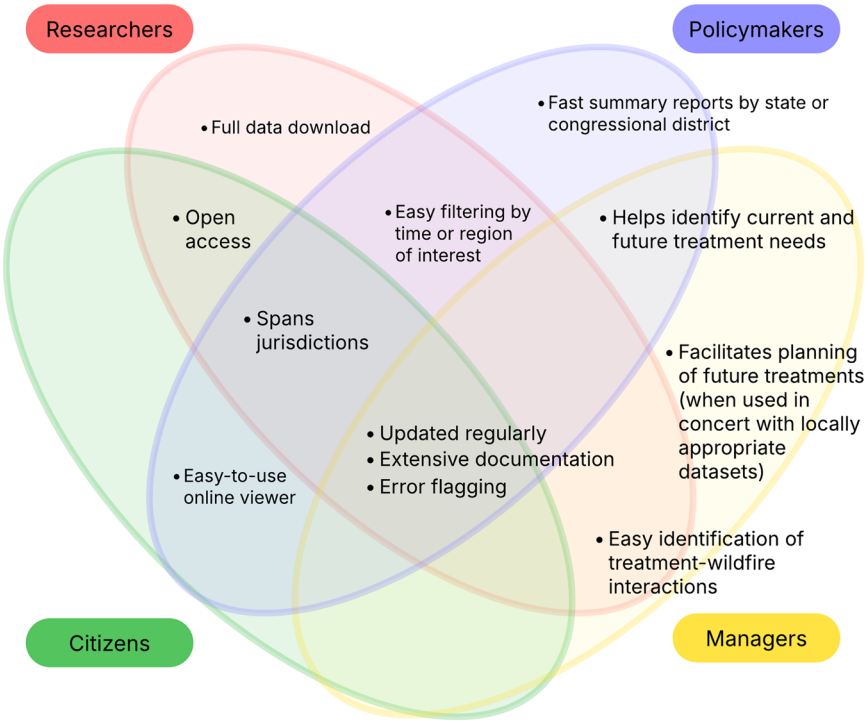

Fig. 1 Venn diagram showing the major groups of potential TWIG (Treatment and Wildfire Interagency Geodatabase) users and highlighting the features of TWIG designed to appeal to each group.

Investment and Jobs Act[10], which specifically authorized the creation of a new, easily accessible, unified database that collates all available information from across the current federal systems of record.

The database described here, the Treatment Wildfire Interagency Geodatabase (TWIG), was developed by the Southwest Ecological Restoration Institutes (SWERI) in response to this federal mandate. TWIG was created to facilitate assessment of existing fuel treatments, plan future treatments, and monitor the continued interactions of treatments and wildfire. TWIG is designed to meet the needs of multiple end users, including congressional representatives and staffers, land managers, engaged citizens, and researchers interested in wildfire-fuel treatment interactions (Fig. 1).

In contrast with many existing systems, TWIG can be viewed and downloaded by anyone without registration. All data and metadata from existing systems of record are collated following an open-source, well-documented, and repeatable protocol. Users can inspect the code and methods used to create TWIG and, if desired, can modify those methods to create their own databases. TWIG aims to include all records of management activities that may be considered fuel treatments, even when fire behavior modification was not a primary objective (e.g., many timber harvests and wildlife habitat improvements). Thus, TWIG has a more complete record of management activities than other databases that focus only on targeted fuel treatments funded by specific hazardous fuels funding sources (e.g., the National Forest System Hazardous Fuels (NFHF) Account of the Forest Service).

TWIG fuel treatment data is compiled from two existing federal systems of public record: the Forest Service Activity Tracking System (FACTS, https://www.arcgis.com/home/item.html?id=f8fb12b1bab44c11b1bee96562cc4773) and the National Fire Plan Operations and Reporting System (NFPORS, https://www.nfpors.gov/) (Table 1). In 2025, the NFPORS system is being phased out of service. A newly-designed database and reporting platform (the Interior Fuels and Post-fire Reporting System, or IFPRS, https://inform-fuels-nifc.hub.arcgis.com/) is already in active use by most agencies in the Department of Interior, and the complete decommissioning of NFPORS is imminent. Successive versions of TWIG are under active development to accommodate this shift from NFPORS to IFPRS. In addition, data from a new collection of fuel treatment records from state forestry and land management agencies and conservation NGOs (the National Fuels Treatment Explorer or NFT, https://nft.garphub.org/) will be included in a future TWIG release (Fig. 2). Though future versions of TWIG will incorporate these additional sources, the version described here includes data from FACTS and NFPORS only.

TWIG is a nationwide database that is suitable for tracking fuel treatment implementation across jurisdictions and large geographic areas. The current version is restricted to federally funded activities and primarily focuses on federal lands, though non-federal data will be added in future releases. With additional refinement and paired with additional data, TWIG is suitable for both local and broad-scale landscape planning, treatment prioritization, and research. However, because TWIG is comprised of data from existing systems of record, it shares many of the same accuracy and completeness limitations of these systems. Future TWIG releases that include data from state agencies will resolve some of these completeness limitations. However, these limitations mean

Owner	Asset name	Asset type	URL
USFS	FACTS Common Attributes – Region 01	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region01.zip
	FACTS Common Attributes – Region 02	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region02.zip
	FACTS Common Attributes – Region 03	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region03.zip
	FACTS Common Attributes – Region 04	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region04.zip
	FACTS Common Attributes – Region 05	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region05.zip
	FACTS Common Attributes – Region 06	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region06.zip
	FACTS Common Attributes – Region 08	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region08.zip
	FACTS Common Attributes – Region 09	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region09.zip
	FACTS Common Attributes – Region 10	ESRI geodatabase	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/Actv_CommonAttribute_PL_Region10.zip
USDI	National Fire Plan Operations and Reporting System (NFPORS)	ArcGIS REST feature service	https://usgs.nfpors.gov/arcgis/rest/services/treatmentPoly/FeatureServer/0

Table 1. URLs used to query the systems of record underlying the Treatment and Wildfire Interactions Geodatabase. Note that there is no Forest Service region 7.

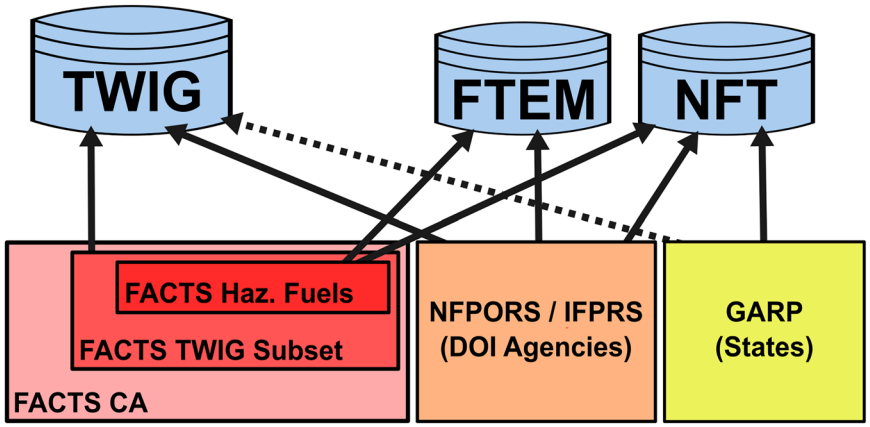

Fig. 2 Conceptual illustration of the relationship between systems of record, TWIG, and other databases that collate fuel treatment records from multiple sources. The arrow from GARP to TWIG is dashed to indicate that this data source is not yet incorporated into TWIG, but planned for future releases. Abbreviations: FACTS (Forest Service Activity Tracking System), CA (Common Attributes), NFPORS/IFPRS (National Fuels Plan Operations and Reporting System/Interior Fuels and Post-fire Reporting System), GARP (Grant Accomplishments Reporting Protocol), TWIG (Treatment and Wildfire Interagency Geodatabase), FTEM (Fuel Treatment Effectiveness Monitoring), NFT (National Fuels Treatment explorer). The NFT explorer and GARP are both parts of the National Fuels Treatments Initiative (https://nft.garphub.org/).

that TWIG is not suitable as a sole data source for critical decision making, especially when high geospatial precision is required. TWIG is not intended for real-time or emergency management use.

Methods

TWIG data sources. *FACTS.* The Forest Service's Forest Activity Tracking System (FACTS) is used throughout the Forest Service to manage information related to Forest Service-funded operations. FACTS is a relational database that contains many linked tables and is not publicly shared in full. However, all records of individual on-the-ground activities are publicly available in FACTS Common Attributes (FACTS CA): a single large table containing all records of individual activities and their associated "common attributes." This expansive dataset is distributed as an ESRI map service, or by Forest Service region as ESRI file geodatabases or (for tabular data only) *.csv files (Table 1).

Most records in FACTS CA are unrelated to wildfire or fuel treatments. In response to demands for better, more focused tracking of fuel treatments[11], the Forest Service distributes a subset of FACTS CA known as FACTS Hazardous Fuel Treatment Reduction data (FACTS HFT). FACTS HFT ostensibly includes all records of

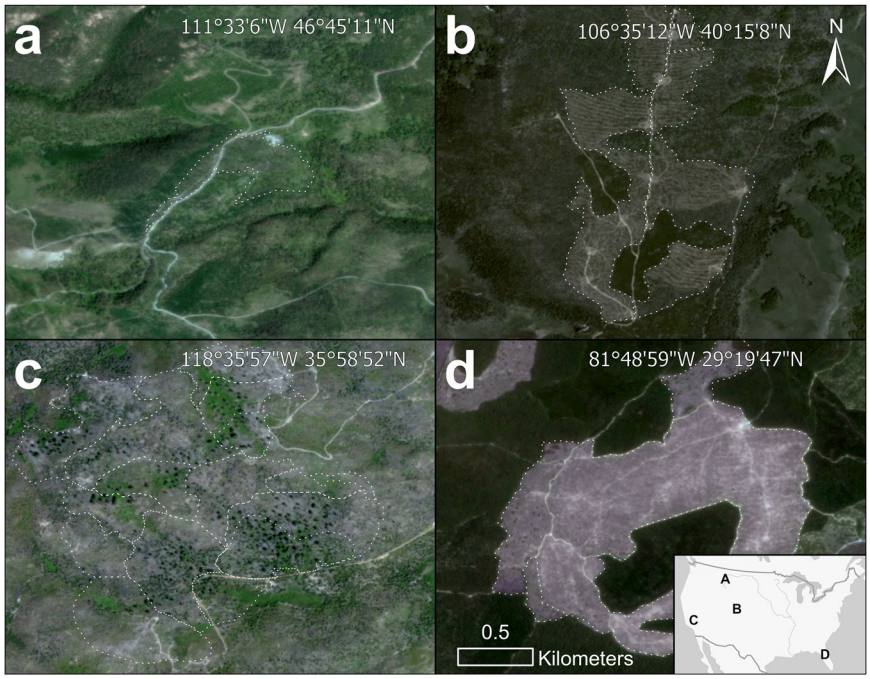

Fig. 3 Examples of management activities recorded in the FACTS (Forest Activity Tracking System) Common Attributes database, but not in the FACTS Hazardous Fuels database. Activity boundaries are outlined in dashed white over true color imagery[20] from the first growing season after the activity occurred. (**a**) Precommercial thin, completed September 28, 2023, Helena National Forest, western Montana. (**b**) Two-aged Shelterwood Establishment and Removal Cut. The completion date is recorded as September 30, 2020, though imagery suggests the actual completion date was between June 2017 and June 2018. Routt National Forest, northwestern Colorado. (**c**) A group of management activities recorded as Piling of Fuels, Hand or Machine and Rearrangement of Fuels, completed October 25, 2023. (**d**) Wildlife Habitat Mechanical treatment, completed March 23, 2022, Ocala National Forest, northern Florida. Images © 2018, 2024 Planet Labs PBC[20].

"vegetative manipulation designed to create and maintain resilient and sustainable landscapes, including burning, mechanical treatments, and/or other methods that reduce the quantity or change the arrangement of living or dead fuel so that the intensity, severity, or effects of wildland fire are reduced within acceptable ecological parameters and consistent with land management plan objectives, or activities that maintain desired fuel conditions."[12] In practice, FACTS HFT is a subset of FACTS CA based on two attribute fields: activity and fund code[12]. While these inclusion criteria fit the needs of some users, they exclude many records of activities that may cause substantive change in fuel and forest structure but lack specific funding from hazardous fuels budgets such as the NFHF Account of the Forest Service or the Wildland Fire Management Account of the DOI.

In contrast with FACTS HFT, TWIG contains a more comprehensive subset of FACTS CA. TWIG includes all records from FACTS HFT plus additional records of activities that may have created substantive changes in fuel but are not associated with the activity or fund code values required for inclusion in FACTS HFT. To determine whether a specific FACTS CA record not included in FACTS HFT warrants inclusion in TWIG, we examined the "activity" attribute in combination with two additional attributes: "method" and "equipment". Many FACTS records have "activity" attribute values not typically associated with fuel modification (i.e., pollinator habitat restoration) but have "method" or "equipment" attribute values that suggest severe changes to fuel loads (i.e., heavy logging equipment) (Fig. 3). To identify these records without inflating false positive errors (i.e., records that are included when they should not be), we developed conservative, rules-based criteria that use the combination of treatment age and size, and the activity, method, and equipment attributes to determine whether a record warrants inclusion (Fig. 4). Our criteria identified approximately 1 M additional records that may be considered fuel treatments – a 156% increase beyond what is available in FACTS HFT. These additional records are clearly identified in TWIG's "data source" attribute field, and the criteria used to determine which records are included (implemented in SQL) are freely available for inspection or modification (see Code Availability).

TWIG data is collected from the Forest Service by downloading the full FACTS HFT polygon file geodatabase and FACTS CA file geodatabases for each Forest Service region (Table 1). FACTS CA records are combined into a single large file, and FACTS HFT records are matched to their corresponding FACTS CA records using a full outer join on their unique identifiers. In some cases, records are successfully matched by their unique identifier, but one or more attribute values are not identical. These discrepancies occur because FACTS CA and FACTS HFT are created and updated by querying the FACTS relational database and thus represent "snapshots" of the database at different times. If a record was updated between the latest releases of FACTS CA and FACTS HFT, there will be a temporary mismatch between the data sources. In all such cases, preference is given to the value recorded in FACTS HFT, regardless of which source was most recently updated. After joining all records

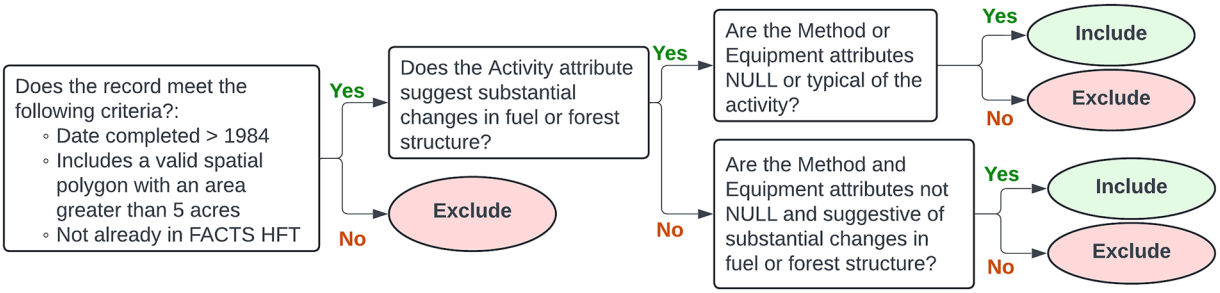

Fig. 4 Flowchart describing the criteria for inclusion of FACTS (Forest Activity Tracking System) Common Attributes records.

from FACTS CA and FACTS HFT into a single, consolidated table, this table is subset to include all records originating from FACTS HFT or meeting our rules-based inclusion criteria. This subset of records is then combined with data from NFPORS/IFPRS before further processing.

NFPORS/IFPRS. NFPORS is an interagency system created by the DOI in the early 2000s to store records of fuel management activities funded primarily by DOI. Though NFPORS is the DOI's current system of record, at the time of writing almost all DOI agencies are no longer adding new data to this system. A new system, the Interior Fuels and Post-fire Reporting System (IFPRS), is under active development and is already in use by most DOI agencies, including: the Bureau of Indian Affairs, the Bureau of Land Management, the Bureau of Reclamation, the Department of Defense, the Department of Energy, the National Parks Service, the Office of Wildland Fire, and the Fish and Wildlife Service. IFPRS is expected to completely replace NFPORS by the end of 2025 (Henry Bastian, DOI, *pers. comm.*). At the time of writing, IFPRS does not yet contain all the historical records contained in NFPORS, and TWIG does not include any IFPRS data. However, the complete decommissioning of NFPORS is imminent, and successive versions of TWIG will be updated to use this source in the future. Because NFPORS and IFPRS share many similarities, the following overview will be of use to many readers indefinitely, and detailed, continuous updates are available online (see Code Availability).

NFPORS was created in the early 2000s in response to the now-defunct National Fire Plan (NFP)[13], and although the NFP has been superseded, NFPORS/IFPRS records are categorized by three of the five NFP "key points": restoration and rehabilitation (key point 2), hazardous fuels reduction (key point 3), and community assistance (key point 4). This contrasts with TWIG data from FACTS, as FACTS HFT also recognizes the NFP "key points" categorization, but only includes activities specifically related to reducing hazardous fuels. NFPORS data is accessed through an ESRI feature service REST API.

Combining data sources. After collecting all FACTS CA- and NFPORS/IFPRS-derived data, both tables are inserted into a single, comprehensive table using a schema crosswalk (Table 2). The crosswalk unites equivalent attribute data from both sources into common attribute fields and generates additional attribute fields to note the original source of key attribute values. After crosswalk, all records are checked for duplicates by comparing their attributes. If two or more records are identical in the "Activity" and "Completion Date" fields, their spatial geometries are compared. If their geometries match (permitting an XY tolerance of ±10 m), the records are flagged as duplicate (but not removed). Finally, to minimize the impact of typographical errors in cost accounting, treatments with costs per acre over $10,000 are flagged (but not removed), as real costs exceeding $10,000 per acre are extremely rare. More extensive error checks are planned for future releases of TWIG (see Technical Validation).

TWIG contains a "key point" attribute that can be found in NFPORS/IFPRS and FACTS data sources, though these attributes are used differently in each source. For instance, the National Fire Plan defines five "key points": 1) firefighting, 2) postfire restoration and rehabilitation, 3) hazardous fuel reduction, 4) community assistance, and 5) commitment to the Wildland Fire Leadership Council. Key points 1 and 5 are generally not applicable to the types of pre-planned, non-emergency forest management activities recorded in TWIG. Though the National Fire Plan was superseded by the Healthy Forests Initiative in 2002 and the National Cohesive Wildland Fire Management Strategy in 2014[14], the notion of key points persists in the wildland fire community.

In FACTS, the inclusion of key point data is not enforced and is often left incomplete. Key point data is not used to construct FACTS HFT, though the records that are included in FACTS HFT almost always have a key point value of = 3 or = 6. Key point 6 is not defined in the National Fire Plan but is used in FACTS to represent activities where fuel reduction was not the primary reason for the activity but is a "secondary benefit". Many FACTS records included in TWIG, especially those from FACTS CA, do not have any recorded key point value. Regardless of the "key point" attribute value, all FACTS records included in TWIG represent activities that likely modified or reduced fuel loads and thus may loosely be categorized as key point 3.

In contrast, NFPORS/IFPRS data included in TWIG contain records with key points = 2, =3, and =4. Key points 2 and 4 generally represent post-fire rehabilitation efforts such as seeding, tree planting, or slope stabilization. Similar post-fire activities exist in FACTS CA (though key point attribute data is often missing), but such records are not included in FACTS HFT. TWIG **does not** include post-fire restoration activities from FACTS. Because TWIG aims to faithfully represent the underlying systems of record and their historical uses,

Attribute Name	Variable Name	NFPORS/IFPRS Source**	FACTS HFT Source	FACTS CA Source
Treatment Name	name	trt_nm	activity_sub_unit_name	name
Unique Treatment ID	id	{nfporsid}-{trt_id}	activity_cn	event_cn
Identifier Database	identifier_database	"NFPORS"	"FACTS Hazardous Fuels"	"FACTS Common Attributes"
Date Current	date_current	modifiedon	etl_modified_date	act_modified_date
Actual Completion Date	actual_completion_date	act_comp_dt	date_completed	date_completed
Acres	acres	gis_acres	gis_acres	gis_acres
Activity code	activity_code	N/A	activity_code	activity_code
Activity	activity	N/A	activity	activity
Treatment Type	type	type_name	treatment_type	nfpors_treatment
Category	category	category	category	nfpors_category
IFPRS Category	ifprs_category	type*	activity*	activity* OR method*
IFPRS Type	ifprs_type	type*	activity*	activity* OR method*
Fund Code	fund_code	isbil*	fund_code	fund_code
Cost Per UOM	cost_per_uom	N/A	cost_per_uom	cost_per_unit
Unit of Measure	uom	"ACRES"	uom	uom
State	state	st_addr	state_abbr	state_abbr
Treatment Date	treatment_date	act_comp_dt OR plan_int_dt OR col_date	date_completed OR date_planned	date_completed OR act_created_date
Date Source	date_source	act_comp_dt OR plan_int_dt OR col_date*	date_completed OR date_planned*	date_completed OR act_created_date*
Fund source	fund_source	isbil*	fund_code*	fund_codes*
Global identifier	globalid	N/A	N/A	N/A
Total Cost	total_cost	N/A	cost_per_uom, uom*	cost_per_unit, uom*
Error flags	errors	[multiple]*	[multiple]*	[multiple]*

Table 2. Attribute crosswalk table for TWIG (Treatment and Wildfire Interagency Geodatabase) and its source databases. *Values are derived (not copied) from this field; see main text for details. **NFPORS (National Fire Plan Operations and Reporting System) is the current data source, but IFPRS (Interior Fuels and Post-fire Reporting System) will replace NFPORS in the coming months. See https://reshapewildfire.org for updates.

the difference in scope between these two systems of record is perpetuated in TWIG. Users may wish to exclude records with key points = 2 or =4 to make the scope of activity records comparable across all source databases.

Data Records

The TWIG database is available at Zenodo[15]. A single zipped file is available: "TWIG_treatment_index_20250709.zip". The filename's suffix indicates the date (July 9, 2025) the archived version was deposited (a continuously updated version is also available – see Code Availability). The zipped file contains one ESRI file geodatabase: treatment_index.gdb. This geodatabase contains a single feature class named "treatment_index". Within this feature class, each record represents the spatial footprint of a single management activity and the associated attribute data. Here, we provide extended definitions for each attribute, including a description of their ultimate point of origin in the source databases:

1. Unique Treatment ID (unique_id): an alphanumeric string that uniquely identifies each record. These identifiers correspond to the event_cn field in FACTS CA and the activity_cn field in FACTS HFT. For records originating from NFPORS, nfporsid and trt_id fields are concatenated following the pattern nfporsid-trt_id.
2. Treatment Name (name): a human-readable name for the record. This field corresponds to the name field in FACTS CA, the activity_sub_unit_name field in FACTS HFT and the trt_nm field in NFPORS. These names are not necessarily unique. In FACTS and NFPORS, names are optional and set by individual users for their own convenience when querying the database. Names typically reflect the local geography and/or a larger project or initiative that encompasses multiple, jointly planned activities (e.g., "Pingree Hill FRP: RX Burn Unit E").
3. State (state): a two-character identifier for the state where the activity occurred. When an activity spans a state boundary, only one state is listed. For all data sources, these values are manually selected from a list of values and not checked against the record's spatial geometry. For records originating from FACTS (CA and HFT), the value is drawn from the state_abbr field. For records originating from NFPORS, the value is drawn from the st_addr field.
4. Acres (acres): the area covered by the activity. Corresponds to the gis_acres field in all source databases. This value is automatically calculated from the spatial polygons in the source databases. We have verified the accuracy of these attribute values by systematically checking against our own measurements of each polygon's area for all records.

5. Treatment Date (treatment_date): a date field representing the management activity's completion date or, for planned activities that have not yet occurred, the planned future date of the activity. When activities have already occurred, the value matches the value of the the "Actual Completion Date" field. For records originating from FACTS CA or FACTS HFT, the value is drawn from the date_completed field (if available). If date_completed is null, the act_created_date (FACTS CA) or date_planned (FACTS HFT) fields are used. For records originating from NFPORS, the value is drawn from the first non-null value of the following: act_comp_dt (actual completion date), plan_int_dt (planned initiation date) or col_date (data collection date) fields. See "Actual Completion Date" for more information on multipart polygons and progressive reporting.
6. Date Source (date_source): a short string denoting the source of the date used to populate the Treatment Date field. This field is dynamically generated when records are first loaded into the database.
7. Identifier Database (identifier_database): an alphanumeric string denoting whether the record originates from FACTS HFT, FACTS CA, or NFPORS. Note that all FACTS HFT records are also included in FACTS CA, but not *vice versa*. Thus, FACTS HFT denotes a record that may be found in FACTS HFT or FACTS CA, and FACTS CA denotes a record that is exclusive to FACTS CA. Corresponding FACTS HFT and FACTS CA records are not included in duplicate; only the record from FACTS HFT is included.
8. Date Current (date_current): a date (MM/DD/YYYY HH:MM:SS) on which the record was last modified in the source database. Corresponds to the etl_modified_date_haz field in FACTS HFT, the act_modified_date in FACTS CA, and the modifiedon field in NFPORS. Across all source databases, these fields are dynamically generated as records are modified.
9. Actual Completion Date (actual_completion_date): a date denoting when the physical work associated with a management activity was completed. Corresponds to the date_completed field in FACTS CA and HFT and the act_comp_dt field in NFPORS. In FACTS, users enter a date manually, with restrictions preventing users from entering future dates. In NFPORS, this field is populated automatically when users check the "Complete?" box for an individual record. Each record can have only one actual completion date, even when the spatial geometry contains multiple polygons. The actual completion date generally refers to the date when all parts of the work were fully complete, even if some parts were completed months or years earlier.
10. Activity code (activity_code): A four-digit number denoting a specific type of management activity. This field corresponds with the activity_code field in FACTS HFT and FACTS CA and is specific to records originating from those databases. The value is set to NULL for records from NFPORS. FACTS activity codes are grouped into the following categories: 1000 – Fire; 2000 – Range; 3000 – Cultural Resources and Recreation; 4000 – Timber and Silviculture; 5000 – Soil, Air, and Watershed; 6000 – Wildlife: Threatened, Endangered, and Sensitive, and Fisheries; 7000 – Vegetation/Restoration; 8000 – Miscellaneous; 9000 – Engineering. The range of values is restricted to the set of activity codes defined in FACTS.
11. Activity (activity): a short string describing the management activity denoted by the FACTS activity code. This field is specific to records originating from FACTS HFT and FACTS CA. The value is null for records originating from NFPORS. For FACTS HFT records, this attribute value is generally a more specific descriptor of the management activity than the "treatment type" and "category" attributes. For FACTS CA records, the "treatment type" and "category" attributes are not defined, and this attribute is the only available description of the type of management activity that occurred.
12. Method (method): A short string describing the method used to complete the management activity. This field is specific to records originating from FACTS HFT and FACTS CA. The value is null for records originating from NFPORS. Though values of this field are chosen by FACTS users from a defined list, different list options describe the method with varying levels of specificity (e.g., "Mechanical" vs. "Single Span Skyline"), reflecting variation in record keeping practices across the FACTS user base. For FACTS CA records, this field is used to help determine whether the record should be included in TWIG.
13. Equipment (equipment): A short string describing the equipment used to complete the management activity. This field is specific to records originating from FACTS HFT and FACTS CA. The value is null for records originating from NFPORS. For FACTS CA records, this field is used to help determine whether the record should be included in TWIG.
14. Category (category): describes the class of treatment types to which an activity belongs (e.g. Fire, Mechanical, Other). This field is mostly applicable to records originating from FACTS HFT and NFPORS; the value is usually NULL for records from FACTS CA. Corresponds with the source field category in FACTS HFT and NFPORS, and nfpors_category in FACTS CA. This attribute describes the "major categorization" for the activity and is less specific than the "type" attribute. The range of values is restricted to the Category Names defined in NFPORS.
15. Type (type): describes the subclass of management activity (e.g. Biomass Removal, Broadcast Burn, Chipping, Fire, etc.). This field is mostly applicable to records originating from FACTS HFT and NFPORS; the value is usually null for records exclusively from FACTS CA. Corresponds with the source fields treatment_type in FACTS HFT, type_name field in NFPORS, and nfpors_treatment in FACTS CA. This field is defined as "the minor categorization for an activity" and provides greater detail than the Category attribute.
16. TWIG Category (twig_category): IFPRS defines five broad categories to classify treatment records: Unplanned ignition (i.e., managed wildfire or natural starts), Planned ignition (e.g., prescribed burns, pile burns, etc.), Mechanical (all hand or machine work, e.g., thinning treatments), Chemical (e.g., herbicide application) and Biological (e.g., grazing for fuel management). To create a consistent system of classification across all source databases, we assign all records to one of these five IFPRS categories. For all records originating from FACTS HFT and most records originating from FACTS CA, this assignment is based on the Activity attribute. For some records originating from FACTS CA, the Activity attribute values are not

typically associated with fuel modification (i.e., pollinator habitat restoration) and provide no insight into which category should be assigned. In these cases, the category is determined by examining the Method attribute. For records originating from NFPORS, the category is determined by the Type attribute. Note that the NFPORS Category and Type attributes are similar, but not equivalent, to the IFPRS Category and Type attributes. The IFPRS category is the only treatment classification that is consistently defined by TWIG for all data sources and all records. The crosswalk tables used to assign IFPRS Category values are based on our domain expertise and best judgement. They are freely available for inspection or modification (see Code Availability).

17. Agency (agency): a short string that identifies the agency primarily responsible for treatment implementation. For records originating from NFPORS, the value is copied from the agency field. For records from FACTS CA or FACTS HFT, the value is set to USFS.
18. Fund Source (fund_source): a short string that categorizes the Fund Code into one of ten broad categories, including No Funding Code (when the fund code in the source database is null) and Multiple (when the source database lists multiple codes).
19. Fund Code (fund_code): a short text string describing the funding source for the management activity. For records from FACTS CA and HFT, this value is derived from the fund_codes and fund_code fields, respectively. The original value is a four-letter fund code from a defined list of values. The full list of fund codes and their definitions are not readily available and may change from year to year with shifts in federal budget rules. To summarize the list of values into more widely understood categories, these fund codes are mapped to one of ten broad classes (See "Fund Source" above). For records from NFPORS, this field is derived from the isbil field, which denotes whether the activity was funded by the Bipartisan Infrastructure Law (i.e., the 2021 Infrastructure Investment and Jobs Act[10]). When isbil is true, the fund code is set to "BIL", otherwise it is set to null.
20. Total Cost (total_cost): a numeric value indicating the total cost of the management activity. For FACTS CA and HFT, this value is derived from the cost_per_uom and uom fields. If uom is ACRES, then the cost_per_uom field is multiplied by the "Acres" attribute to calculate the total cost. If the value of the uom field is EACH, then the cost_per_uom field is assumed to represent the total cost and is copied directly. NFPORS does not contain a cost field; the value is null for records originating from this database.
21. Cost Per UOM (cost_per_uom): a numeric value representing the per-acre cost of the management activity. These values represent estimated direct costs in U.S. dollars at the time of the activity's completion (i.e., not inflation-adjusted) and do not include planning or overhead support costs. For all source databases, these values are estimated and manually entered by end users. They are not reconciled with financial statements and are not used for budgeting purposes. Extreme values in this field are likely errors, and it appears plausible that they may originate from typos or mistakenly entering total costs rather than costs per acre (*pers. comm*. U.S. Forest Service staff, see Technical Validation for additional information on error checking and flagging). Corresponds with the cost_per_uom or cost_per_unit fields in FACTS HFT and CA (respectively). For records originating from NFPORS, the value is null.
22. Unit of Measure (uom): For records originating in FACTS CA or FACTS HFT, the value is pulled from the uom field and may be ACRES, EACH, or null. There is no corresponding field in NFPORS, so the value is null for these records. This field is used to determine whether the "Cost Per UOM" field represents the cost per acre or the total cost of a management activity. When the value is null and the "Cost Per UOM" field is valid, the total cost of the activity is calculated by assuming acres are the unit of measure.
23. Error flags (error): A text string flagging possible errors in the record. The following flags are currently defined:

    a. DUPLICATE-KEEP: Record has duplicates but should be kept as the representative record.
    b. DUPLICATE-DROP: Record has duplicates and should be dropped.
    c. HIGH COST: Cost per acre > $10,000

    If multiple flags apply, they are concatenated with a semicolon separator (e.g., DUPLICATE-DROP;HIGH COST).
24. Object ID, Shape, Shape length, Shape area, (OBJECTID, shape, shape_Length, shape_Area): these fields are automatically generated when TWIG is distributed as an ESRI file geodatabase. They specify a unique identifier, geometry type, perimeter length (in meters), and area (in square meters). For the shape field, the value is always Polygon Z, as TWIG does not include any records associated with point or line geometries (though such records sometimes occur in the source databases).

Technical Validation

Because TWIG is designed to accurately represent the underlying systems of record, errors in those systems are perpetuated in TWIG. Though errors are not corrected or removed, TWIG includes an "Errors" attribute that can be used to identify many of the records that are likely to contain errors. Known issues include duplication, incomplete or inaccurate spatial geometries, and inaccurate data in attribute fields.

Duplicate records. Duplicate records occur when a single management activity is recorded multiple times in a single database or when the activity is recorded in separate databases which are subsequently merged. TWIG considers records to be erroneously duplicated when the completion date and activity code or type exactly match, and the spatial geometries intersect with 95% or more overlap. Because the same management activity can be repeated multiple times and different management activities may co-occur in the same area, records

with non-matching completion dates and activity codes or types are not considered duplicates. Approximately 57,000 records encompassing 1.2 M ha (3% of all records, 2.3% of total record area) were identified as potential duplicates.

When duplicate records are identified, all records in the matching set are flagged in the "Errors" attribute. The most complete record (or, if records are equally complete, the record with the most recent edits) is flagged with "DUPLICATE-KEEP", and other matches are flagged with "DUPLICATE-DROP", allowing users to exclude unwanted duplicates with a simple query. However, users should be aware that the attributes used to identify duplicates may be incorrect, and flagged records may actually represent different activities that occurred at the same time or the same activity that was repeated at different times. When practicable, we recommend that users inspect duplicate records in their region of interest and validate them with external data, such as repeat aerial images.

Completeness and accuracy of spatial geometries. The completeness and accuracy of spatial geometries were not assessed as part of this data integration, though some errors are known to exist. Published accuracy assessments are rare, but not absent: in a study of FACTS HFT data in California, trained observers compared FACTS polygons with those from a Landsat-based change detection algorithm[16]. The observers noted that just 54% of FACTS polygons were matched with a polygon from the change detection algorithm, and of this 54%, only 79% were closely matched (±25% error in total area). Thus, over half of all examined FACTS HFT records were either undetectable or had spatial geometries that were poorly matched with detectable changes. Though not all management activities are expected to create detectable changes in land cover, an identical analysis of CALFIRE (California's state forestry and wildfire agency) fuel treatments showed that 80% of activities were detectable. In sum, this research suggests that both spatial inaccuracies and errors of commission (i.e., records of management actions in areas where they did not occur, or false positives) occur within FACTS data, though this may vary depending on region and ecosystem type.

Errors of omission (i.e., missing records of management actions that did occur, or false negatives) are more difficult to identify, but a recent study of forest management activity in New Mexico[17] lends some insight: omission errors were quantified by comparing data collected from regional- or state-level offices to data collected from specific requests and in-person visits to local offices. Omission error rates in the regional- and state-level data ranged from 0% to 57.4%, averaging 7.4% of the treated area across the five HUC-10 watersheds where error was quantified[17]. Though these error rates encompass federal, state, and private data (the current version of TWIG only includes federal data), this result does provide a benchmark for the frequency of omission errors in TWIG. As TWIG currently only contains fuel treatments conducted by federal agencies, areas of interest with a high concentration of federal lands likely have more accurate records of treatments that areas with a high proportion of private lands.

A related question is whether wildfires should be included as "treatments"—a key issue for agencies that report "total acres treated" as a benchmark of management activity. Recording practices differ among agencies, regions, and through time. To highlight the complexity of this issue, consider the U.S. Fish and Wildlife Service (USFWS), a DOI agency. USFWS does not count wildfires as management activities, except for the parts of wildfires that burn through planned treatments, that are included in the immediate 3-year workplan, and that meet the objectives of those planned treatments. Furthermore, USFWS has not counted any recent wildfires occurring in Alaska, even when the fires were managed for resource benefit objectives (Christopher Marks, U.S. Fish and Wildlife Service, *pers. comm.*). Other agencies may vary in any or all of these reporting requirements, reporting requirements are not constant, and records may not be retroactively updated when requirements change. The only way to resolve this issue is to compare management activity data and wildfire data on a case-by-case basis to determine when and where wildfires were included as management activities. The online TWIG viewer provides tools and data to facilitate these comparisons (see Code Availability).

The accuracy of the spatial geometry is likely to vary with the age of the recorded activity and the data input method. Some older records (especially pre-2005) were only described by a single point or general administrative boundary and a measure of total area[16]. More recent spatial geometries are more likely to be recorded with handheld GPS or manual digitization of aerial imagery. Furthermore, the spatial extents of some management activities are hard to define, such as thinning, sanitation cuts, and prescribed fires. Spatial polygons for these activities typically describe the encompassing area, though fuel and forest structure may only be modified on a fraction of the landscape within that area. TWIG makes no distinction between spatial geometries recorded in different ways or at different spatial scales.

Accuracy of information recorded in attribute fields. TWIG records contain extensive attribute data (see Table 2). A large federal workforce manually enters these data; thus, errors are inevitable. The frequency of errors is impossible to assess in most cases. The accuracy of dollar costs (Cost Per UOM field) is particularly difficult to assess: accounting practices may differ among agencies and regions, values are not reconciled with actual expenditures, and values often do not reflect programmatic, planning, and compliance costs (Forest Service and DOI staff, *pers. comm.*). However, some errors in direct cost estimates can be identified simply by their extreme values. These errors can arise as typos or when values are mistakenly recorded as *total* cost rather than cost *per unit area*. All records with cost values exceeding a value of $10,000 per acre are flagged in the "Errors" attribute, allowing users to exclude these records with a simple query. Real costs in excess of $10,000 per acre are possible, but rare; users should validate these records with external data when possible.

Another important attribute to consider is "Actual Completion Date". These dates denote the day that physical work for a given management activity was completed. Users should note that a substantial portion of the work may have been completed weeks or months prior to the final day of work. Additionally, these dates are manually entered and are not externally verified. In some cases, land managers may not know the precise completion

Features	TWIG	FTEM	NFT
USDA FACTS Hazardous Fuels data	Yes, 1984-present	Yes, 2019-present	Yes, 2005-present
USDA FACTS Common Attributes data	Yes (subset), 1984-present	No	No
USDOI NFPORS data	Yes	Yes	Yes
USDOI IFPRS data**	Coming soon	Yes	Yes
State data (Grant Accomplishments Reporting Portal)	Coming soon	No	Yes
Download any data	Yes	No	No
Open access	Yes	No (federal employees only)	Yes
Open source	Yes	No	No
National (United States) scope	Yes	Yes	Yes

Table 3. Comparison of TWIG (Treatment and Wildfire Interagency Geodatabase), FTEM (Fuels Treatments Effectiveness Monitoring), and NFT (National Fuels Treatment) data resources, highlighting the utility of TWIG. *IFPRS (Interior Fuels and Post-fire Reporting System) is the successor to NFPORS (National Fire Plan Operations and Reporting System). At the time of writing, most Department of the Interior agencies have begun active use of IFPRS. However, NFPORS remains the only source for historical (>3 years old), though historical records will soon be included in IFPRS and NFPORS will be decommissioned.

date, and will enter a date near the end of the fiscal year in which the activity was completed (September 30th) instead of the actual completion date (USDA and DOI staff, *pers. comm.*). Simplifying to calendar year of completion—rather than day of completion—can reduce bias relating to the timing of treatment activities across a unit.

Impact of errors and uncertainty. Because TWIG does not remove or correct errors in the underlying systems of record, users must filter and validate the data to ensure it meets their requirements. Without external validation, spatial imprecision makes TWIG data unsuitable for fine-scale mapping, planning, or analysis (e.g., of single treatment projects, stands, or trees). Furthermore, attribute data should be carefully examined and independently verified (when possible) before conclusions are drawn. Special consideration should be given to cost values ("COST_PER_UOM"): though extreme cost errors are flagged, variation in accounting practices create substantial uncertainty, and values should be considered rough estimates.

Usage Notes

Intended use, strengths, and limitations. TWIG is a transformative tool for wildfire management and ecological restoration, offering comprehensive data integration and accessibility. It combines data from federal systems of record, including FACTS and NFPORS, using carefully developed criteria to capture treatments that affect forest structure and wildfire behavior. Unlike many tools restricted to agency use, TWIG is accessible to a broad audience, promoting collaboration among federal agencies, NGOs, researchers, policymakers, and local stakeholders (Fig. 1). We anticipate that TWIG will facilitate policy development and planning for wildfire risk mitigation and research on the ecological, economic, and societal effects of fuel reduction treatments. By integrating data across jurisdictional boundaries, TWIG supports shared stewardship and cross-boundary collaboration, with partners like the National Association of State Foresters (NASF) extending its reach to state-level data in planned future releases. Additionally, TWIG addresses data quality challenges by highlighting gaps and inconsistencies, encouraging data owners to prioritize improvements while fostering transparency. With its broad scope, TWIG supports diverse users and applications and evolves through iterative development and user feedback, ensuring it remains adaptable to future needs.

However, TWIG has limitations. TWIG data should not be used for real-time decision support, emergency management, small-scale mapping, planning, or analysis (e.g., of single treatment projects, stands, or trees), or other uses requiring real-time or precise data. Users should note that TWIG is a harmonized aggregation of legacy and operational datasets and thus shares many of the same accuracy and completeness limitations as these systems. Spatial accuracy may vary, particularly for older records, and cost data may be inconsistent due to manual entry and lack of reconciliation with actual expenditures, as discussed above. The reliability of TWIG improves with spatial and temporal scale. Analyses conducted at fine spatial resolution or short time frames (e.g., stand-level or annual summaries) should be interpreted cautiously. Though TWIG implements some error flagging, it does not correct errors in the source data, requiring users to filter and validate information for specific needs. TWIG's coverage primarily includes federal data and does not yet incorporate state, private, or NGO data, though we plan to extend the scope of TWIG data in future releases. While versatile, TWIG is not universally applicable, and specialized tools may be better suited for specific local-scale tasks. These limitations emphasize the need to understand TWIG's intended use and complement it with other tools when necessary.

TWIG is also one of several United States-wide databases that collate fuel treatment records from multiple sources. Two other resources of note are the Fuels Treatments Effectiveness Monitoring (FTEM) database and the National Fuels Treatments (NFT) initiative (Fig. 2, Table 3, http://172.26.0.86:8080/). Like TWIG, these databases contain records of fuel treatments from multiple systems of record, and the information they contain

overlaps substantially with TWIG. However, each database was created for a distinct purpose, and their methods of data collation differ substantially. Users should consider all available fuel treatment databases and choose the one best suited to their needs.

Disclaimer. The authors of this paper and all source data providers (the U.S. Government, U.S. Department of Agriculture, U.S Department of the Interior, USDA Forest Service and their employees and contractors) assume no legal liability for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed herein. The authors and source data providers make no warranty, express or implied, including warranties of merchantability and fitness for a particular purpose with respect to documents or information available in TWIG. All indirect, consequential, implied, punitive and special damages are deemed waived if you use the information in TWIG in any manner. Additional information is available at the following links: https://data.fs.usda.gov/geodata/edw/edw_resources/meta/Actv_CommonAttribute_PL_Region01.xml (for FACTS data) and http://www.wildfire.gov/disclaimer (for NFPORS data).

Data availability

The TWIG database is available on Zenodo[15] at the following link: https://doi.org/10.5281/zenodo.15851622. The download includes a single zipped file containing an ESRI file geodatabase (see Data Records for a detailed description of the contents). All TWIG data are freely available for reuse or modification with attribution (Creative Commons BY 4.0)[18].

Code availability

All TWIG data, metadata, and processing methods are freely available for reuse or modification with attribution (Creative Commons BY 4.0 and General Public License v3)[18,19]. All code used to create TWIG is available at https://github.com/Innovate-Inc/sweri-data-tools. The repository includes release notes, links to additional metadata from the original systems of record, and an extensive README file. The README file includes the most up-to-date TWIG metadata and extensive notes for users who wish to develop their own extensions or modifications of TWIG.

A continuously updated version of TWIG can be downloaded as an ESRI file geodatabase in its entirety (https://reshapewildfire.org/resources/twig-data-resources) or accessed through an interactive online viewer (https://reshapewildfire.org/twig/layers).

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References

1. Westerling, A. L. & Increasing Western, U. S. forest wildfire activity: sensitivity to changes in the timing of spring. *Philos. Trans. R. Soc. B Biol. Sci.* **371**, 20150178 (2016).
2. Parks, S. A. & Abatzoglou, J. Warmer and drier fire seasons contribute to increases in area burned at high severity in Western US forests from 1985 to 2017. *Geophys. Res. Lett.* **47** (2020).
3. Prichard, S. J., Povak, N. A., Kennedy, M. C. & Peterson, D. W. Fuel treatment effectiveness in the context of landform, vegetation, and large, wind-driven wildfires. *Ecol. Appl.* **30**, e02104 (2020).
4. Davis, K. T. *et al.* Tamm review: A meta-analysis of thinning, prescribed fire, and wildfire effects on subsequent wildfire severity in conifer dominated forests of the Western US. *For. Ecol. Manag.* **561**, 121885 (2024).
5. Coop, J. D., Parks, S. A., Stevens-Rumann, C. S., Ritter, S. M. & Hoffman, C. M. Extreme fire spread events and area burned under recent and future climate in the Western USA. *Glob. Ecol. Biogeogr.* **31**, 1949–1959 (2022).
6. Vorster, A. G. *et al.* Metrics and considerations for evaluating how forest treatments alter wildfire behavior and effects. *J. For.* **122**, 13–30 (2024).
7. Chamberlain, C. P. *et al.* Learning from wildfires: A scalable framework to evaluate treatment effects on burn severity. *Ecosphere* **15**, e70073 (2024).
8. Prichard, S. J. & Kennedy, M. C. Fuel treatments and landform modify landscape patterns of burn severity in an extreme fire event. *Ecol. Appl.* **24**, 571–590 (2014).
9. Shive, K. L. *et al.* Thinning with follow-up burning treatments have increased effectiveness at reducing severity in California's largest wildfire. *For. Ecol. Manag.* **572**, 122171 (2024).
10. *Infrastructure* Investment *and* Jobs Act. vol. H.R. 3684 1039 (2021).
11. USDA Office of Inspector General. *Forest Service Wildland Fire Activities - Hazardous Fuels Reduction Audit Report*. https://usdaoig.oversight.gov/reports/other/final-action-verification-audit-forest-service-wildland-fire-activities-hazardous (2016).
12. Tansey, M. Hazardous fuels reduction treatments: tracking and accomplishment reporting requirements (2024).
13. Managing the Impact of Wildfires on Communities and the Environment: A Report to the President in Response to the Wildfires of *2000*. (Council on Environmental Quality, 2000).
14. Lee, D. C. *et al. A National Cohesive Wildland Fire Management Strategy*. https://www.forestsandrangelands.gov/documents/strategy/reports/1_CohesiveStrategy03172011.pdf (2014).
15. Call, A. *et al.* A new geodatabase of fuel treatments across federal lands in the USA. *Zenodo* https://doi.org/10.5281/zenodo.15851622 (2025).
16. Knight, C. A. *et al.* Accurate tracking of forest activity key to multi-jurisdictional management goals: A case study in California. *J. Environ. Manage.* **302**, 114083 (2022).
17. Withnall, K., Tomczyk, N., Zebrowski, J. & Dappen, P. A database of vegetation treatments in New Mexico, USA and surrounding regions. *Data Brief* **55**, 110680 (2024).
18. Deed - Attribution 4.0 International - Creative Commons. https://creativecommons.org/licenses/by/4.0/.
19. The GNU General Public License v3.0 - GNU Project - Free Software Foundation. https://www.gnu.org/licenses/gpl-3.0.en.html#license-text.
20. Planet Labs PBC. Planet Application Program Interface: In Space for Life on Earth (2024).

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Author contributions
Aaron Kimple, Andrew Sánchez Meador, Melanie Colavito, and Camille Stevens-Rumann developed TWIG's initial design and directed all subsequent work, with assistance and feedback from all authors. Patricia Dappen, Dana Heusinkveld, Stephanie Mueller, Ben Holloway, Keaton Shennan, Katahdin Withnall, Jennifer Herring, and Anson Call further developed TWIG's design and implementation. Anson Call, Nathan Tomczyk, Katahdin Withnall, and Camille Stevens-Rumann drafted the manuscript with assistance and feedback from all authors.

Competing interests
The authors declare no competing interests.

Additional information
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